Ionospheric Forecast Model with Dynamic GPS Assimilation

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LONG-TERM GOALS

1. Develop a global ionospheric and upper atmospheric forecasting model over a range of spatial and temporal scales with space and ground-based data assimilation capability

2. Develop an improved understanding of the basic dynamics, structure, and energization mechanisms in the global ionosphere-thermosphere system

OBJECTIVES

1. Develop nonlinear Eulerian model of global ionospheric dynamics including magnetospheric and upper atmospheric coupling

2. Develop methods and techniques for assimilating total electron content data derived from the space-based Global Positioning System (GPS) directly into global ionospheric forecast model

3. Validate model forecast parameters with ground and space based datasets

4. Compare model forecasts with empirically-based ionospheric specification models

APPROACH

A set of first-principles equations of continuity, momentun, and energy have been solved using finite-difference numerical techniques and applied to global ionospheric dynamics. The model is three-dimensional, time-dependent, and can assimilate data products in a variety of formats. A plasmaspheric extension to the model has been developed based on existing empirical models and data. The lower boundary of the plasmaspheric model is a diffusive equilibrium boundary condition. The model physics includes ion production due to solar EUV, resonantly scattered radiation, and auroral processes, ion-neutral chemical reactions, thermal conduction, neutral composition changes, thermospheric wind inputs, electrodynamic drifts, field-aligned diffusion, local heating and cooling processes, and parameterization of mesoscale processes. Empirical model inputs are arbitrary magnetospheric electric field distributions, low latitude electric fields, auroral electron precipitation, magnetic fields, neutral winds, neutral densities, and high altitude electron heat fluxes. The code outputs are O^+, NO^+, O_2^+, N_2^+, H^+, T_e, and T_i globally. The approach to assimilate GPS observations into the global first-principles code uses a nudging or Newtonian relaxation technique which is commonly used in lower atmospheric weather forecasting in collaboration with Edward Barker of the Atmospheric Forecasting

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and Prediction group of the Naval Research Laboratory in Monterey, California. Some processing of GPS data was performed in collaboration with Michael Reilly of Geoloc Corp. using a GPS receiver at Westford, Massachusetts. Typically one to two hours of differential phase path data from available GPS satellites in view are processed The differential phase path time series for a single path is modelled as the sum of an ionospheric term which is proportional to total electron content along the path and a bias term related to satellite motion and receiver characteristics. The assimilation of total electron content in analogous to the assimilation of precipitable water for lower atmospheric forecasting.

WORK COMPLETED

1. Global Ionospheric Prediction Model (GIPM) implemented and run on NRL in-house computer (Origin 2000 and SGI) for a variety of initial conditions

2. GPS data processed from Westford, MA station for selected days in December 1997

3. Newtonian relaxation method for assimilating time-dependent GPS data developed and implemented in model

4. Model run with and without GPS datasets and compared with Millstone Hill incoherent scatter radar observations

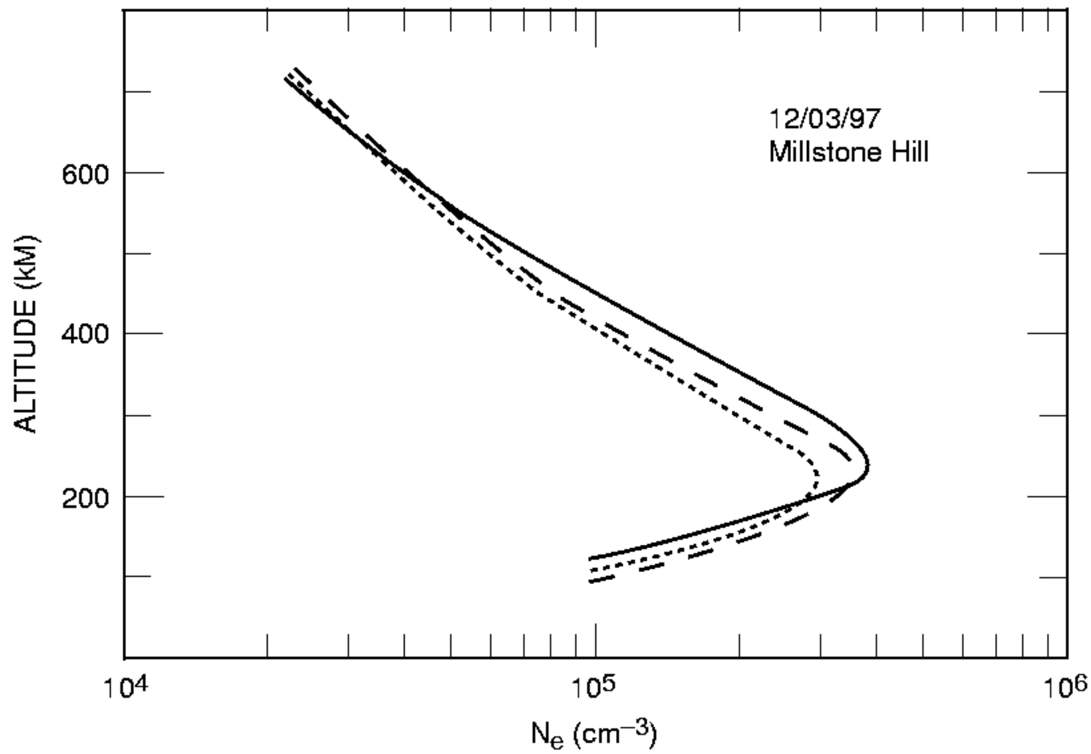
5. F-region electron density profile from ionospheric forecast code compared with profile from ionospheric specification model ITRAY

RESULTS

GPS data has been assimilated into GIPM ionospheric forecast code for a range of relaxation parameters using a Newtonian relaxation technique. The assimilation of GPS data has been performed with varying degrees of success. The forecast F-region electron density profile at the location of Millstone Hill is dependent on the relaxation parameter used in the code. For a specific range of the relaxation parameter magnitude we have found that the assimilation improves the model prediction of the electron density profile at Millstone Hill. For other values of the relaxation parameters no significant improvement was seen. Figure 1 shows a comparison between the model prediction with and without assimilation and Millstone Hill incoherent scatter radar observations.

IMPACT

The preliminary results of this work indicate that space-based GPS data assimilation may potentially improve the ionospheric forecast of F-region parameters under certain conditions. However, a larger range of relaxation parameters associated with the Newtonian relaxation assimilation techniques must be studied along with larger range of GPS averaging times. Multiple GPS inputs should be included in the analysis and the fusion of GPS and other data sources is needed. In addition, the data assimilation must be performed for disturbed geophysical conditions and be further validated using ground and space-based observations.



TRANSITIONS

The NRL GIPM is being used by Geoloc Corp. to compare with their static ionospheric specification model. In addition we are collaborating with the NASA Jet Propulsion Laboratory with their Navy GEOSAT Follow-on project to provide ionospheric compensation using the GPS network.

RELATED PROJECTS

In the area of global ionospheric modelling, Utah State University and the National Center for Atmospheric Research are currently engaged. However the effort at NRL is the first to develop techniques for assimilating GPS data into a global Eulerian first-principles model and to validate the model forecasts with ground and space-based data.

PUBLICATIONS

Keskinen, M.J., M. Reilly, and M. Singh, Ionospheric Forecast Model with Dynamic GPS Assimilation, *Geophys. Res. Lett.*, submitted, 1998.

Keskinen, M.J., S.L. Ossakow, S. Basu, and P.J. Sultan, Magnetic-flux-tube-integrated evolution of equatorial ionospheric plasma bubbles, *J. Geophys. Res.*, *103*, 3957, 1998.

Keskinen. M.J., Ionospheric Forecasting using the Global Positioning System, *NRL Review*, submitted, 1998.